



Small Wind Turbines and Towers

Small Wind Systems Tutorial
Village Power Conference Workshop



Part 2

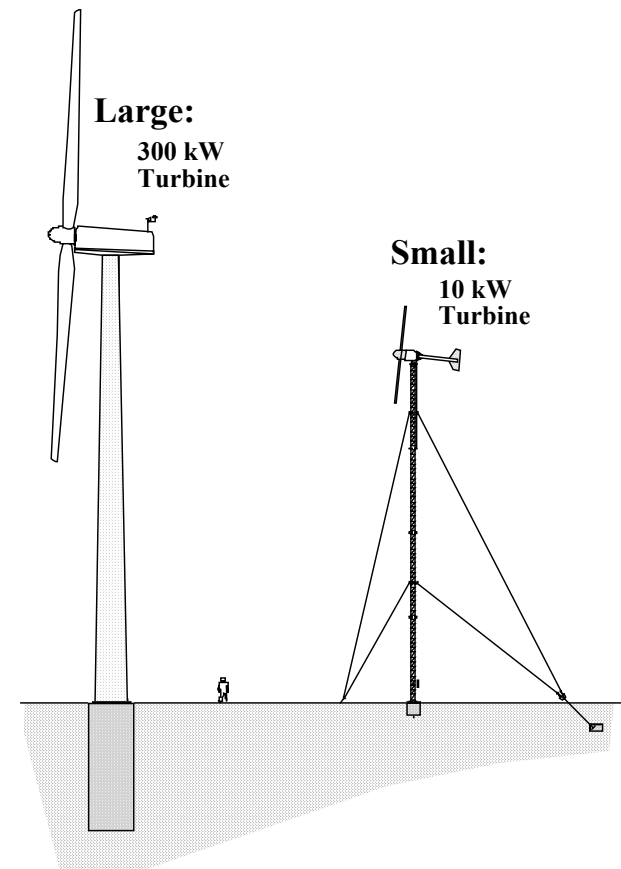
Small Wind Turbines are Different

◆ Large Turbines (500-1500 kW)

- Installed in “Windfarm” Arrays
Totaling 1 - 100 MW
- ~ \$1,000/kW; Designed for Low
Cost of Energy
- Requires 6 m/s (13 mph) Average
Sites

◆ Small Turbines (0.3-50 kW)

- Installed in “Rural Residential” On-
Grid and Off-Grid Applications
- ~ \$2,000-4,000/kW; Designed for
Reliability / Low Maintenance
- Requires 4 m/s (9 mph) Average
Sites



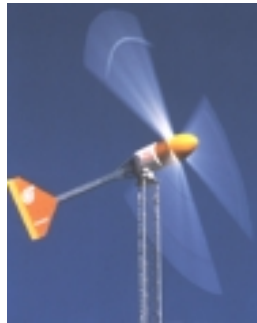
More Expensive, but Also More Valuable



Large Turbines

- ❖ ~ \$1,000 / kW
- ❖ High Voltage Delivery
- ❖ Value of Power:

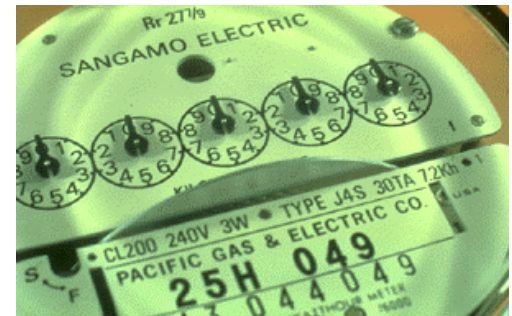
2-5¢



Small Turbines

- ❖ ~ \$2 – 3,000 / kW
- ❖ Low Voltage Delivery
- ❖ Value of Power:

6-18¢

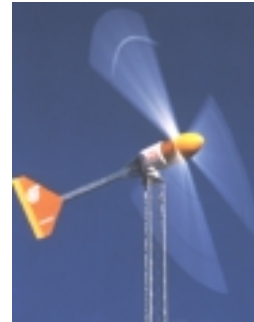


Small Turbines Require Less Wind ...



Large Turbines

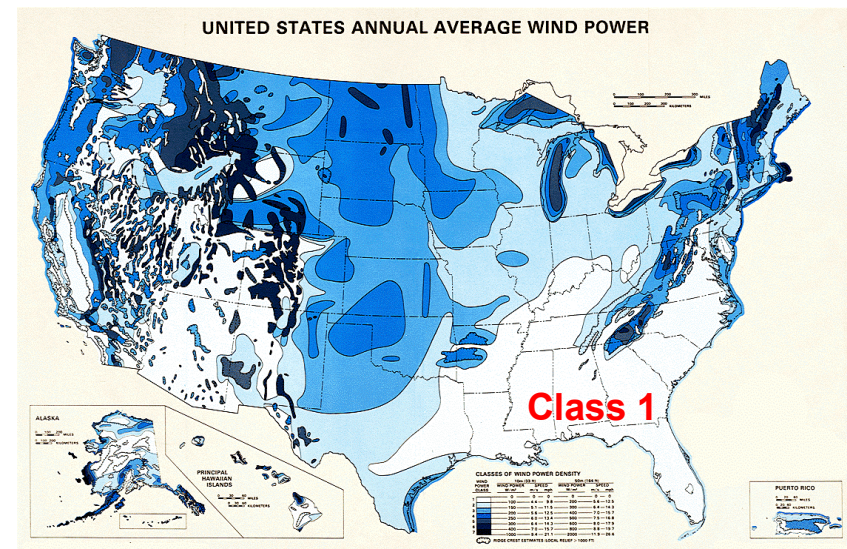
- ❖ Require ~ Class 3-4 Wind Regime
- ❖ Prefer Class 5



Small Turbines

- ❖ Require ~ Class 2 Wind Regime

... So They
Work
More Places



Modern Small Wind Turbines:

High Tech, High Reliability, Low Maintenance


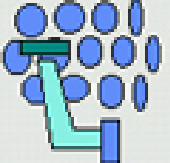
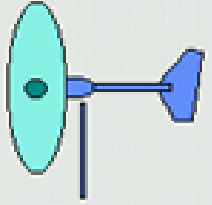
- ❖ **Products from 400 W – 50 kW**
- ❖ **Technically Advanced**
- ❖ **Only 2-3 Moving Parts**
- ❖ **Very Low Maintenance Requirements**
- ❖ **Proven: ~ 2,000 On-Grid and ~ 40,000 Off-Grid Installations**



(Not to scale)

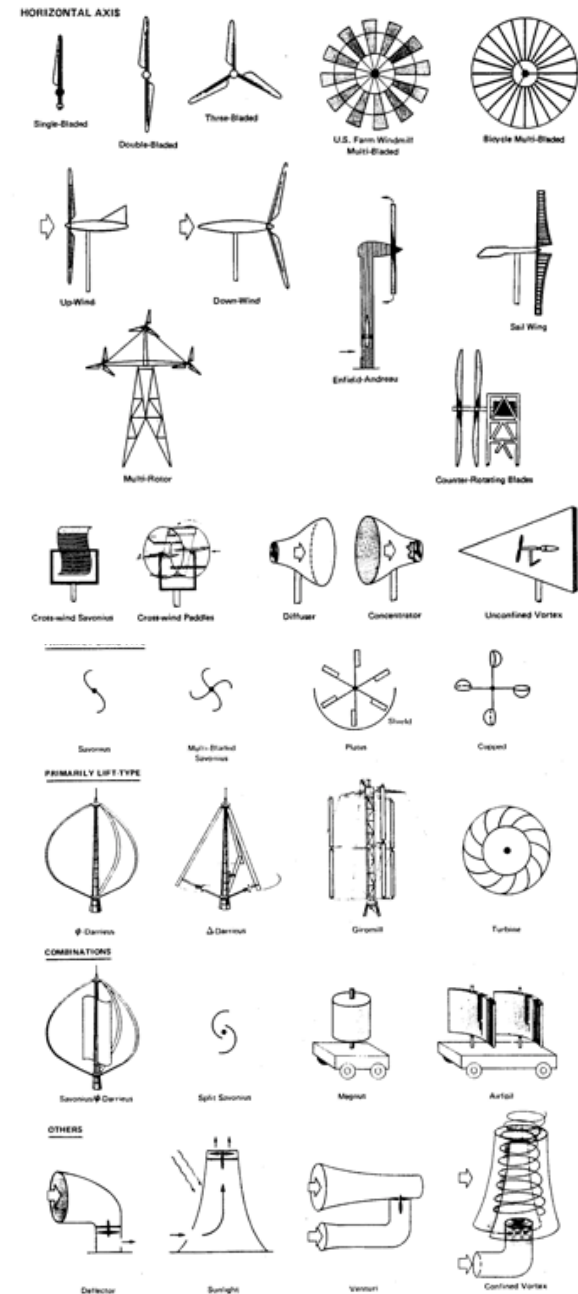


Small Wind: Least Cost Now and Probably Always

Status of the Technologies			
	Photovoltaics	Solar Thermal	Small Wind
Status	Commercial	Demo	Commercial
Installed Cost	\$ 8 / Watt	\$ 10 / Watt	\$ 3.20 / Watt
Payback Period	30 Years	30+ Years	15 Years
Cost Potential	\$ 3 in 2010	?	\$ 1.50 in 2010
Typical Site	Suburban	Southwest	Rural
Available Resources	Poor - Good	Poor - Good	Poor - Great

Turbine Configurations

- ◆ Hundreds of Possible Configurations
... **Most are Bad**
- ◆ Bad Configurations Keep Showing-up
and Wasting Valuable Resources:
 - Savonius Vertical-Axis Rotor
 - Darrieus Vertical-Axis Rotors
 - Cloth-Blade, Sail Wings Rotors
 - Windmill Rotor with Electrical Generator
 - High-Speed Mechanical (CWD)
 - Venturies or Other Flow Concentrators



Technical Challenge

◆ Difficult Operating Environment:

- Energy Inflows from 38 W/m² (4 m/s) to 94,500 W/m² (54 m/s)
- 7,000+ Operating Hours per Year
- 75 Million Cycles per Year: > 2 Billion in 30 Year Life
- High Gusts, High Turbulence, Lightning, Icing, Salt, Spray, Sand, Etc.
- Difficult Maintenance Environment

◆ Dispersed Installations Means Expensive Maintenance & Repairs

◆ Reliability is Paramount

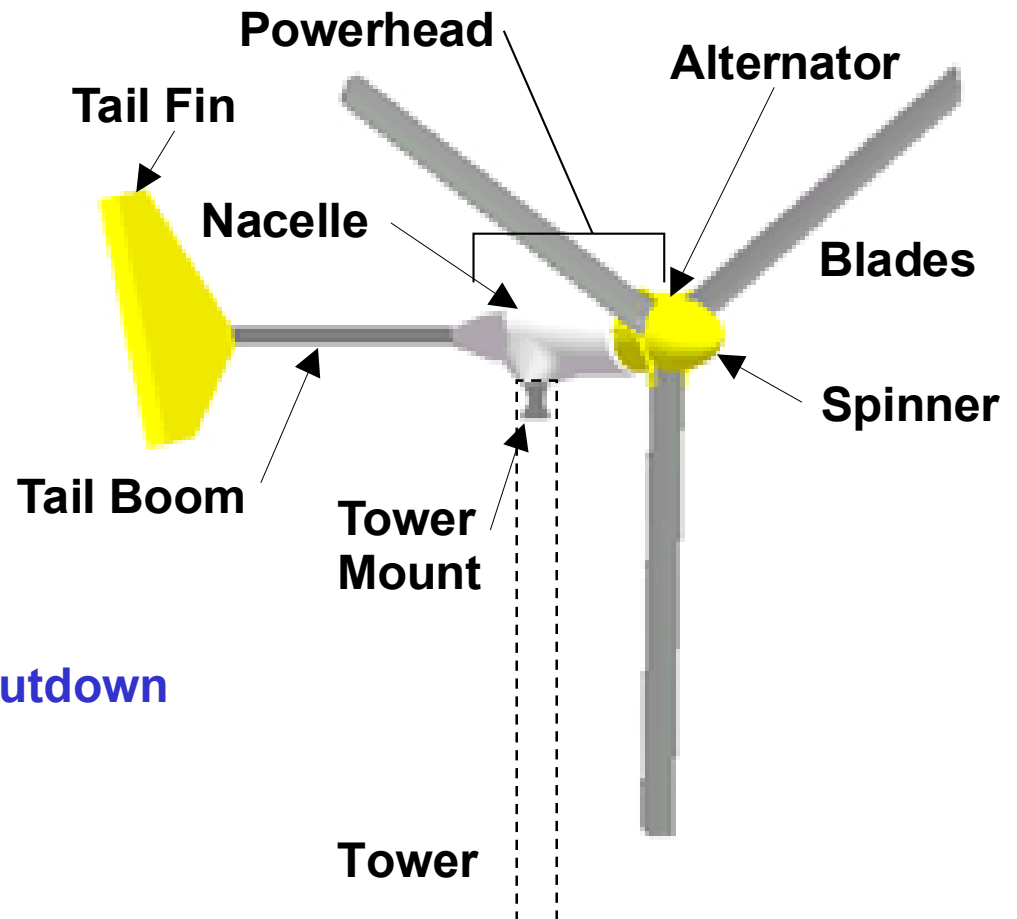
All Leading Small Turbine Products are Mechanically Simple and have a Similar Configuration



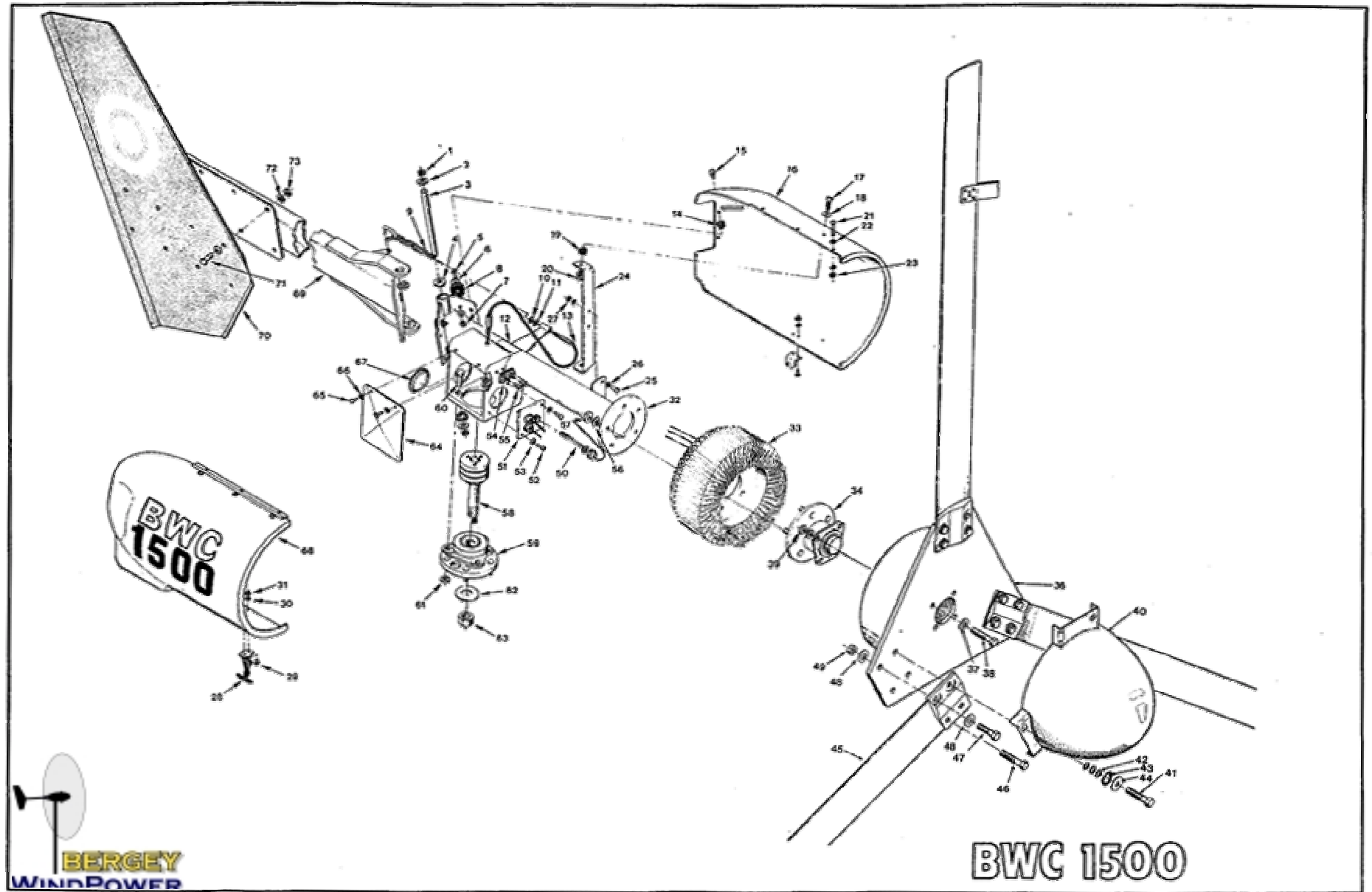
Generic Small Wind Turbine

Mechanically Simplicity ... Few Moving Parts

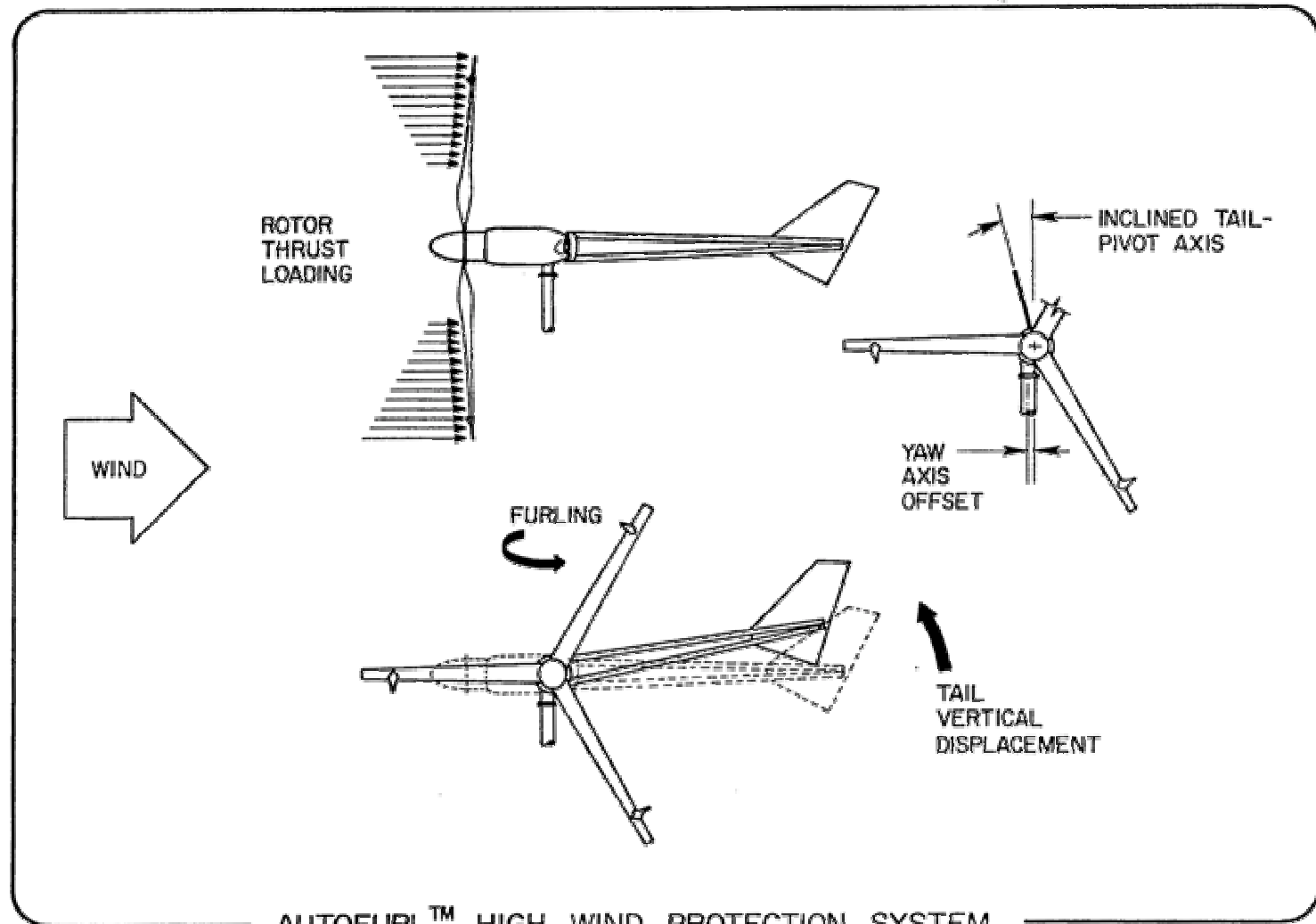
- ◆ 3 Blade Rotor - Fixed Pitch
- ◆ Special “Integrated” Direct Drive Generator, Usually Permanent Magnet Type
- ◆ Tail Aligns Rotor to Wind
- ◆ Passive Overspeed Protection by Furling, Either Up or to Side
- ◆ No Mechanical Brake ... Shutdown with Electrical Braking



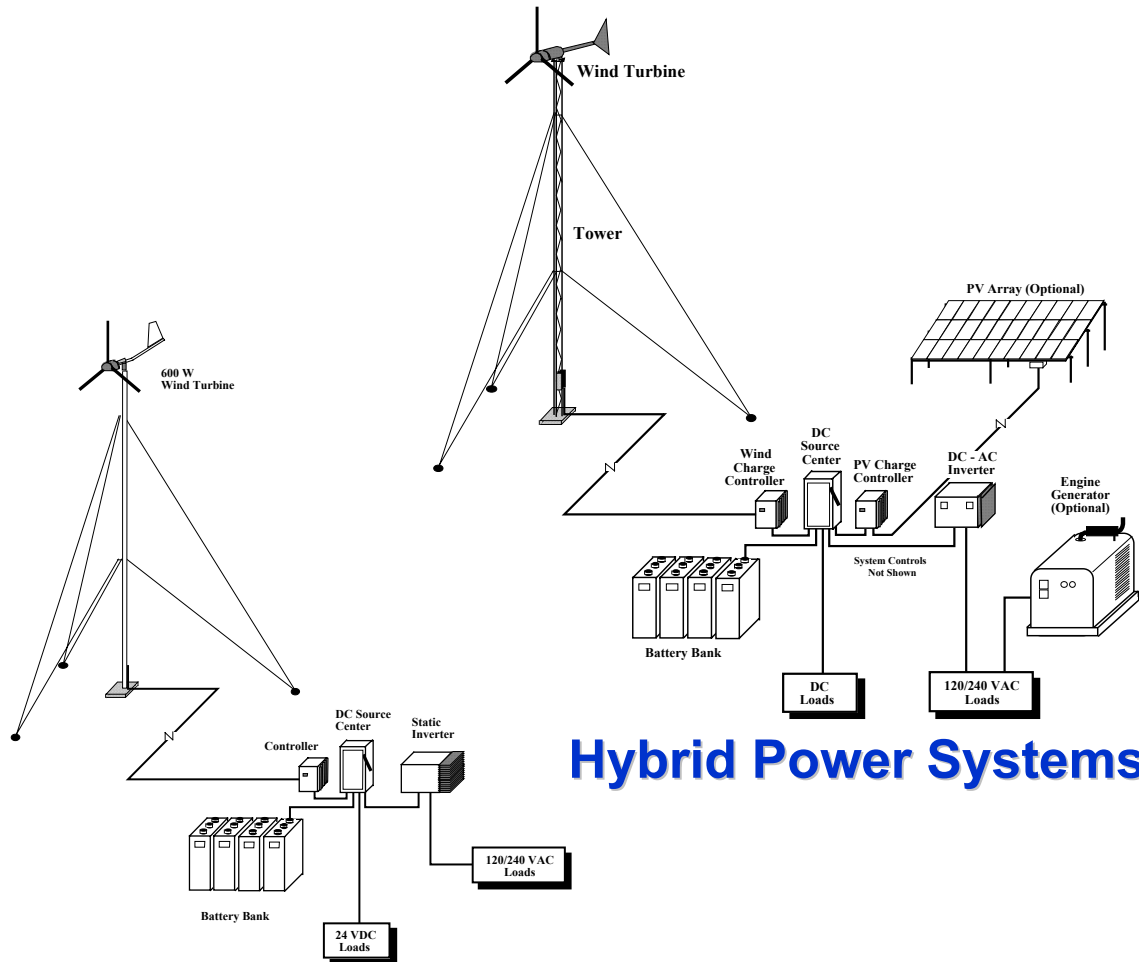
Small Turbine Parts



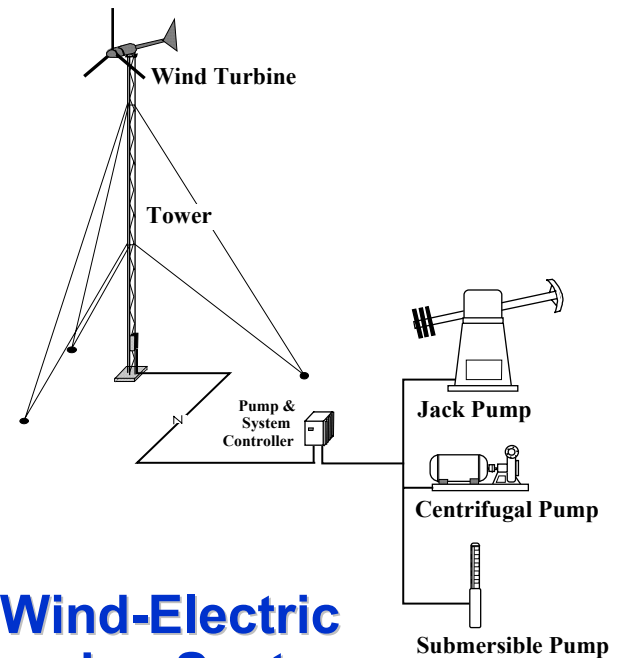
Furling: Passive Protection



Small Wind Applications



Hybrid Power Systems

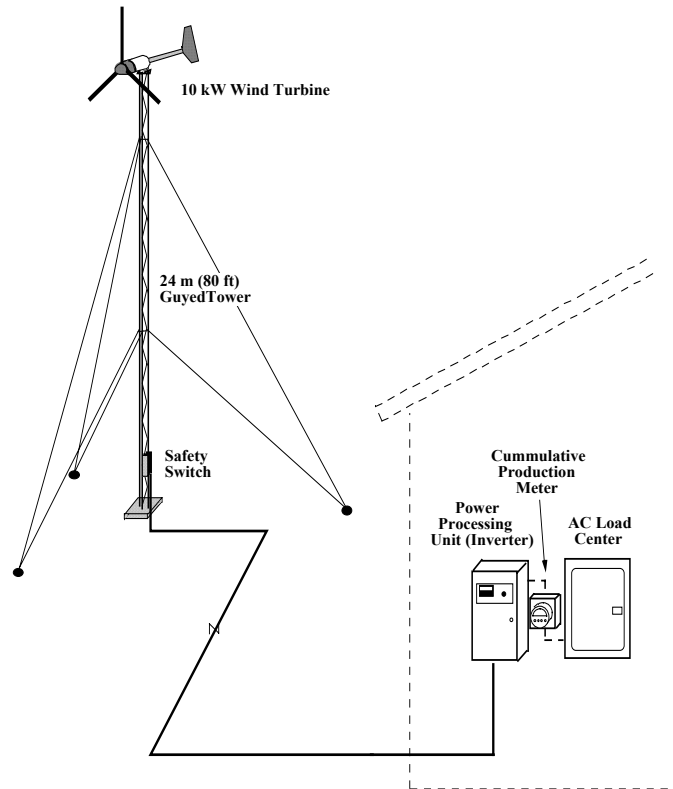


Wind-Electric Pumping Systems

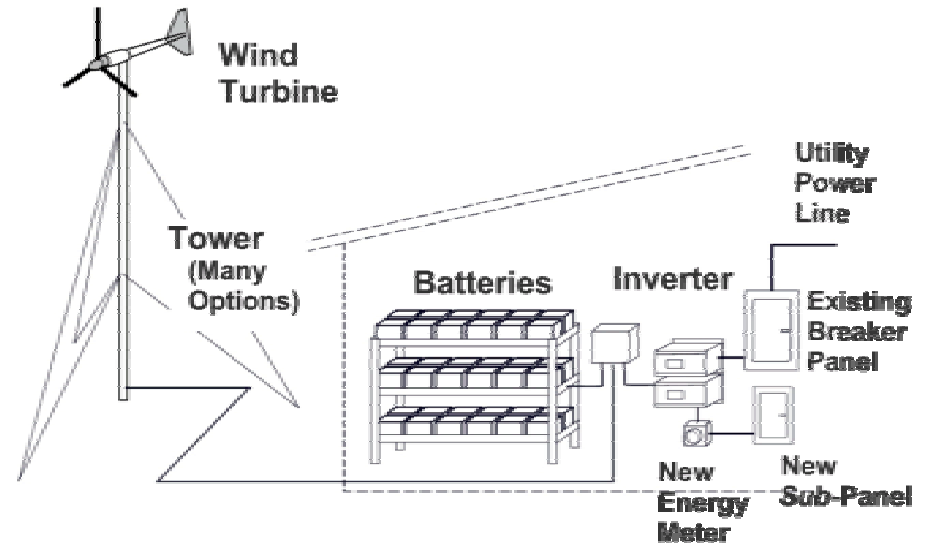


Wind Home Systems

On-Grid Systems



Grid-Intertie

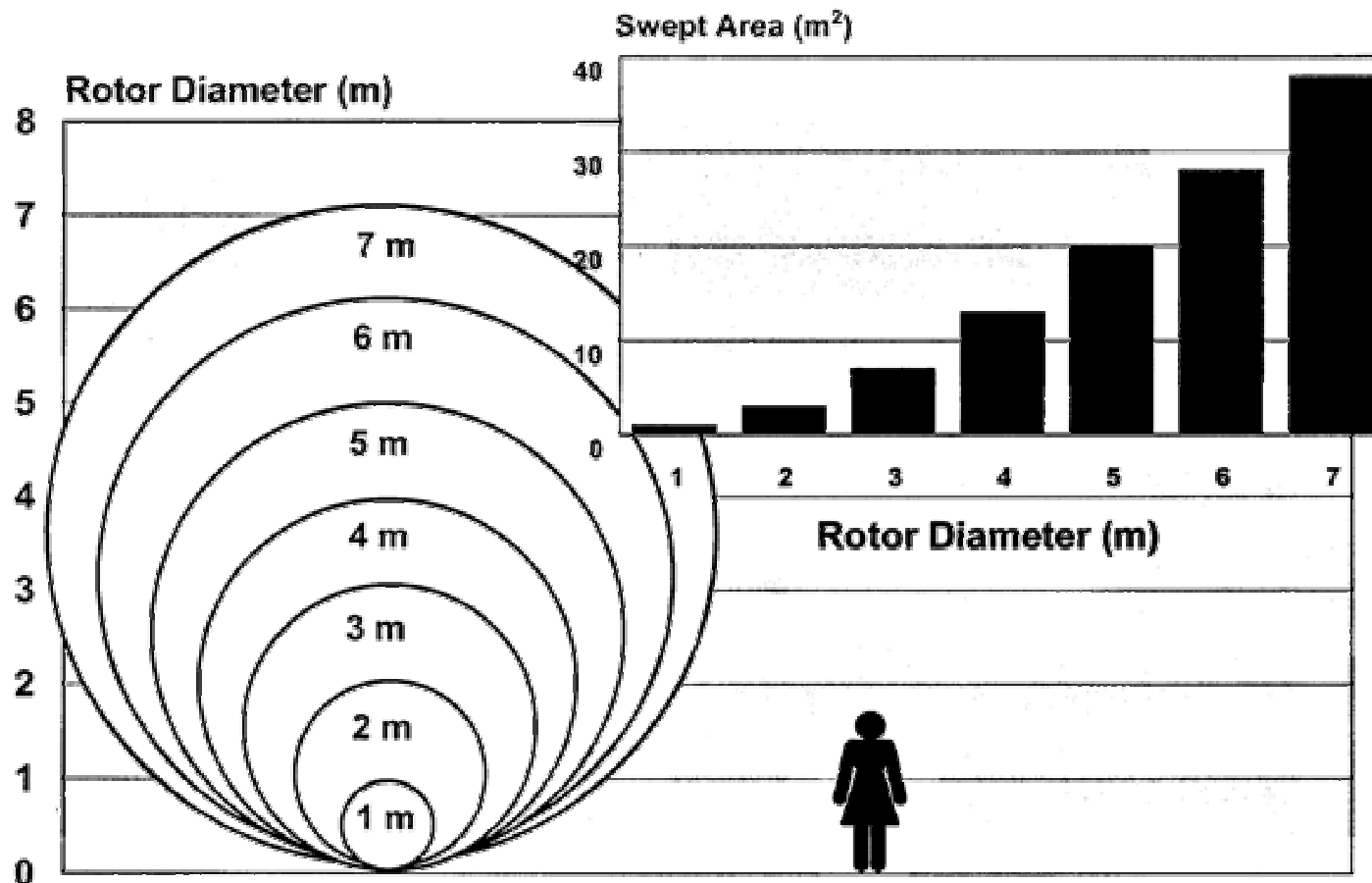


Intertie + Back-up



Rotor Size

Relative Size of Small Wind Turbines



Courtesy of Paul Gipe

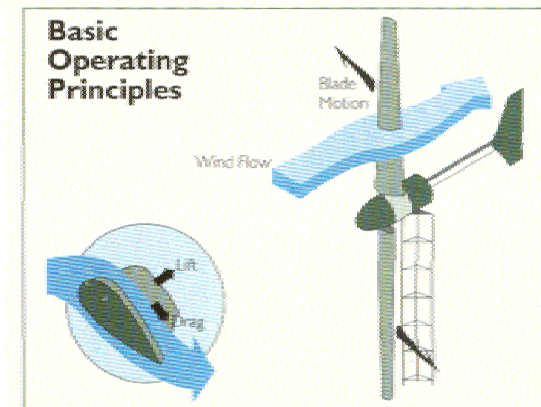


Small Turbine Rotors

- ❖ **Blades are the Most Critical Component of a Small Wind Turbine**
- ❖ **3-Bladed Rotors Run Smoother Than 2-Bladed Rotors**
- ❖ **Fiberglass or Plastic Are Preferred Materials ... Avoid Metal (Fatigue) and Wood (Maintenance)**
- ❖ **Blades Create the Turbine Noise**
- ❖ **Rotor Efficiency Varies with Blade Design: 20 – 45%**
- ❖ **New Airfoils are Boosting Performance Dramatically**



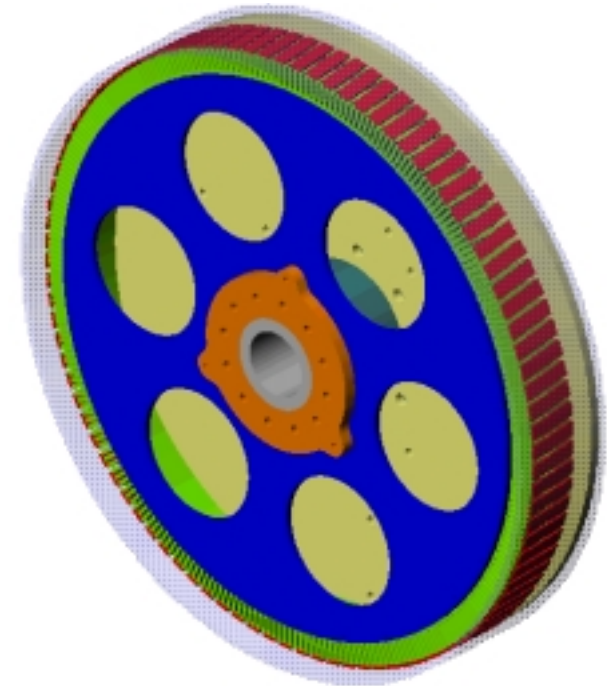
BWC SH3032 Airfoil



**SWWP
Whisper H40**

Generators / Alternators

- ❖ **Standard Generators Require Higher Speeds Than a Wind Turbine Rotor Can Deliver**
- ❖ **Use of Speed Increasing Belts or Chains Must be Avoided due to Very Poor Reliability**
- ❖ **Most Manufacturers have Developed Their Own Custom Low Speed Generators**
- ❖ **Both Rotating Shaft and Rotating Case Configurations are Used**
- ❖ **Most Alternators use Permanent Magnets**
- ❖ **Industry Switching from Ferrite to Neodymium “Super Magnets”**



Electrical Controls

- ❖ **Controls Usually Limited to Battery Overcharge Protection**
- ❖ **Unlike Solar, Wind Turbines Normally Sold with Matched Controller**
- ❖ **Simple On-Off Charge Regulators Seem to be Adequate**
- ❖ **Controllers Often the Least Reliable Component**
- ❖ **Paralleling Independent Controllers on DC Bus Works Well**
- ❖ **Easy User Adjustability is Not a Good Feature ... Due to Possibility of Misuse**



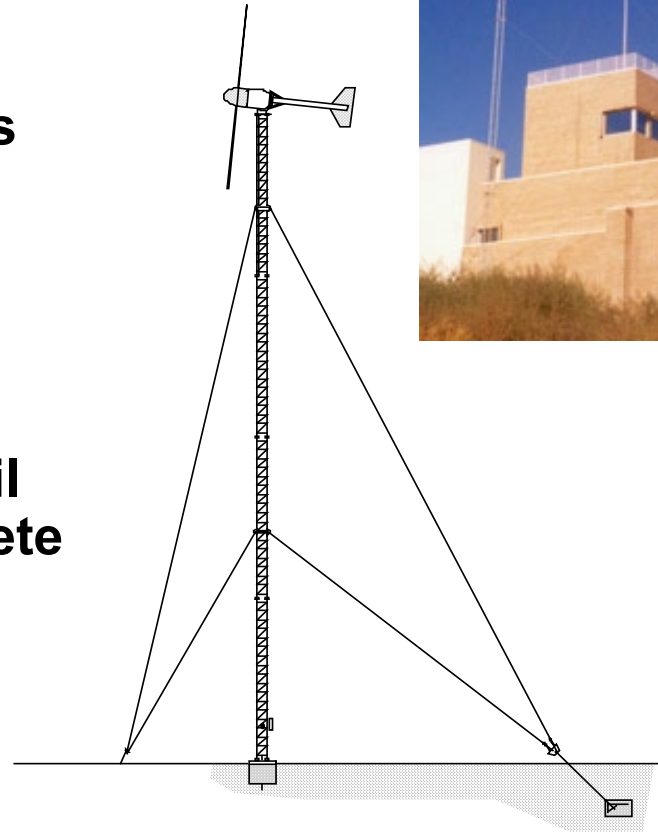
Towers for Small Turbines

- ❖ **Putting a Wind Turbine on a Tower That is Too Short is Like Mounting a Solar Module in the Shade**
- ❖ **Towers Should be 12 m (40 ft) Minimum**
- ❖ **Towers of 24 - 37 m (80-120 ft) Recommended**
- ❖ **Taller Towers Cost More, But Nearly Always Lower Life-Cycle Costs Due to Performance Improvement**
- ❖ **Hot-Dip Galvanized Steel is the Most Common Tower Material**
- ❖ **Effective Tower Grounding is an Important Part of Lightning Protection**



Guyed-Lattice Towers

- ❖ Least Expensive Type ... Efficient Use of Materials
- ❖ Good Siting Flexibility
- ❖ Easily Erected with Gin-Pole on Smaller Systems (>10 kW)
- ❖ Periodic Monitoring of Guy-Wire Tension Required
- ❖ Simple, Inexpensive Civil Works ... Minimal Concrete Requirements

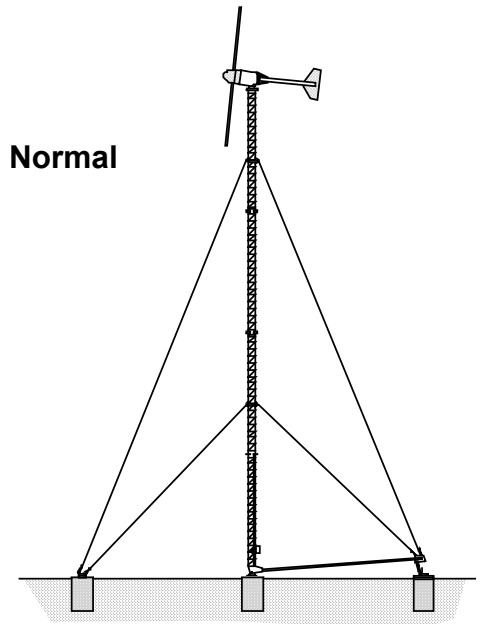


Tilt-up Towers

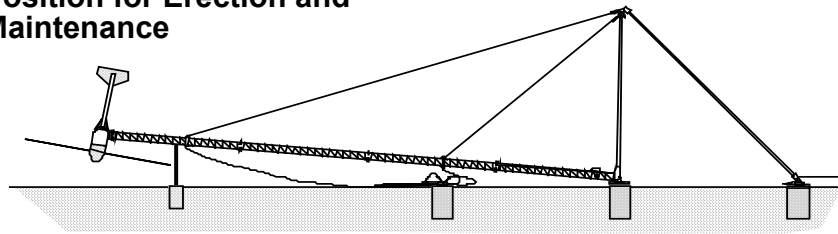
- ❖ Cost is ~30% More Than Non-Tilting Tower
- ❖ Easy to Erect Without a Crane
- ❖ Must have 4-Way Guying
- ❖ Raising With Hand Winch Possible
- ❖ Good Choice for Typhoon Affected Areas



Tilt-up Tower in the Normal Operating Position

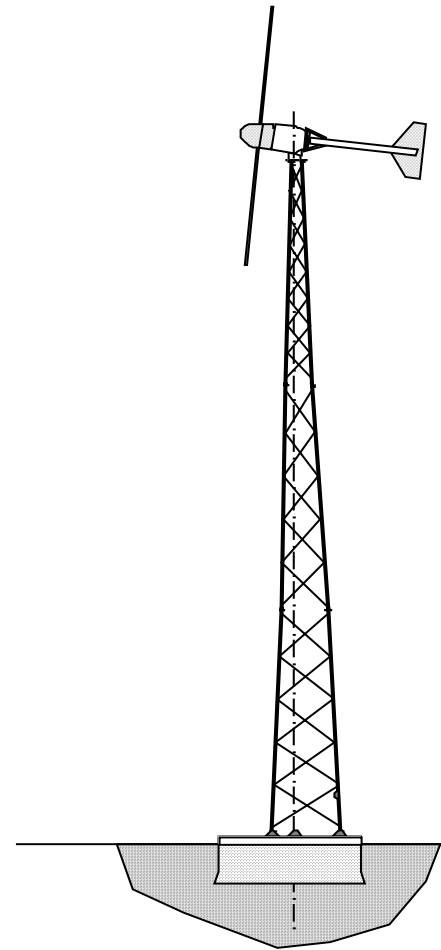


Tilt-up Tower in the Lowered Position for Erection and Maintenance



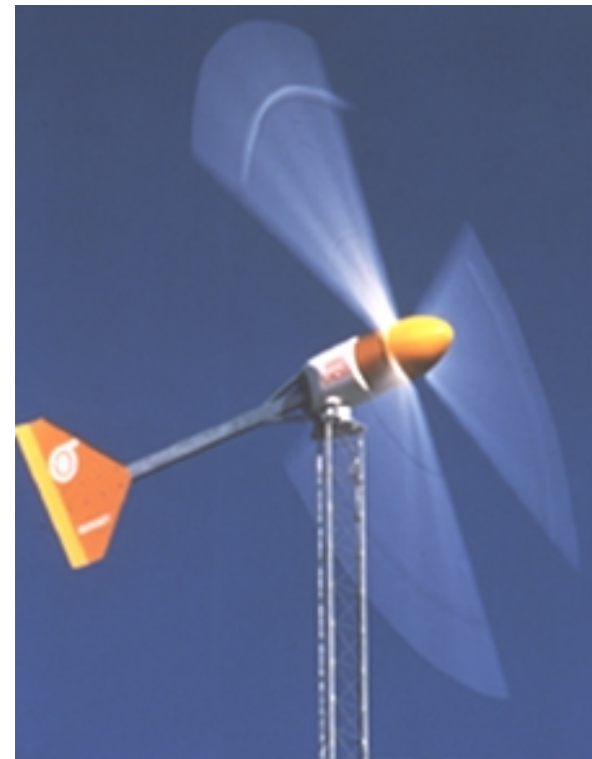
Self-Supporting Towers

- ❖ Cost is ~50-100% More Than Guyed-Lattice Tower
- ❖ Smallest “Foot-Print”
- ❖ Requires Substantial Civil Works
- ❖ Must be Heavy Duty to Provide Proper Stiffness
- ❖ Wood Poles Can be Used for Smaller Units



Shopping for Small Wind Turbines

- ❖ **Power Ratings are Deceiving Due to Differences in Rated Wind Speeds ... Best Comparison is Energy Production at Same Average Wind Speed**
- ❖ **Reliability and Operating Life are Design Specific ... Small Design Details are Important**
- ❖ **Membership in National Trade Association is Good Sign**
- ❖ **Talk to Actual Users About Operating Experience**



Reliability and Maintenance

- ❖ **Turbines Operate Unattended and Automatically, Even in Severe Weather**
- ❖ **Reliability and Maintenance Requirements are Design Specific ... Look for:**
 - Simplicity of Design
 - Fiberglass Blades
 - Direct Drive, Brushless, Generators
 - Heavy Weight Structural Elements
 - Corrosion-Resistant Materials and Finishes
- ... and Check Supplier Reputations!**
- ❖ **Best Available Units Require No Scheduled Maintenance and can Operate for 3-6 Years Without Attention**
 - Inspection Recommended Every 2 Years
 - At 3-6 Years, Blade Leading Edge Tape Must be Renewed
- ❖ **Typical Design Operating Life is 30 Years (Some Small Turbines Have been Operating for More Than 60 Years!)**



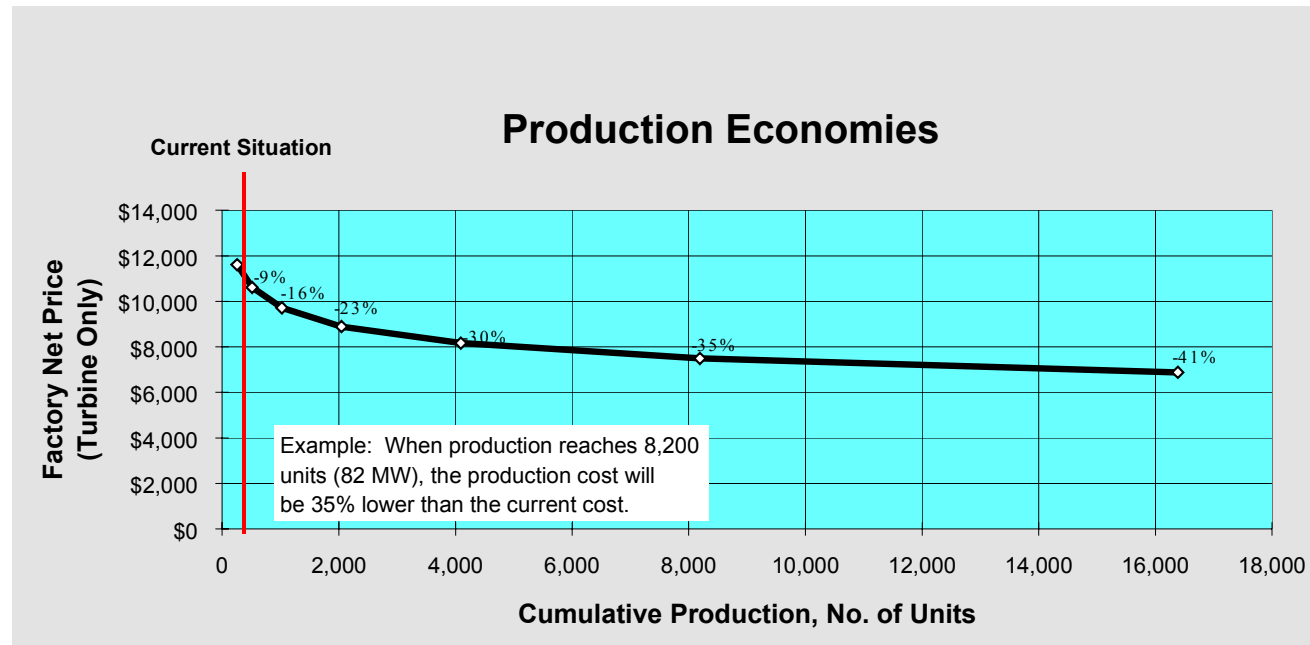
Barriers to the Market

Why Aren't There More Small Turbines

- ❖ High Costs: Low Production Volume & Historical Lack of Subsidies
- ❖ Reliability Problems with Light Weight and Inadequate Designs
- ❖ Other Technologies have Received the Limelight and More Private & Public Investment
- ❖ Wind Resources have been Systemically Underestimated



Volume Production will Drive Costs Down by 15 – 30%



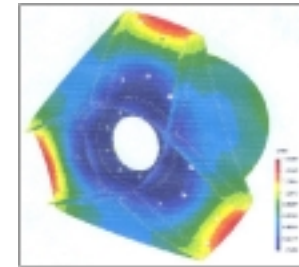
“ a ceiling fan on steroids”



New Technology is Lowering Costs

US-DOE Advanced Small Wind Turbine Program + Industry Funded R&D

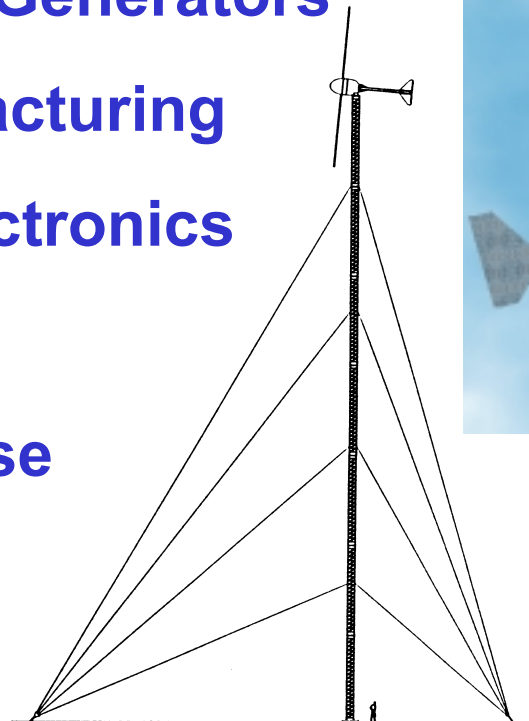
- ❖ **Advanced Airfoils**
- ❖ **“Super-Magnet” Generators**
- ❖ **Low Cost Manufacturing**
- ❖ **Smart Power Electronics**
- ❖ **Very Tall Towers**
- ❖ **Stealth: Low Noise & Visual**



3D Solid Modeling



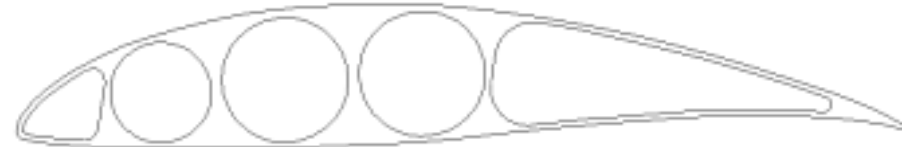
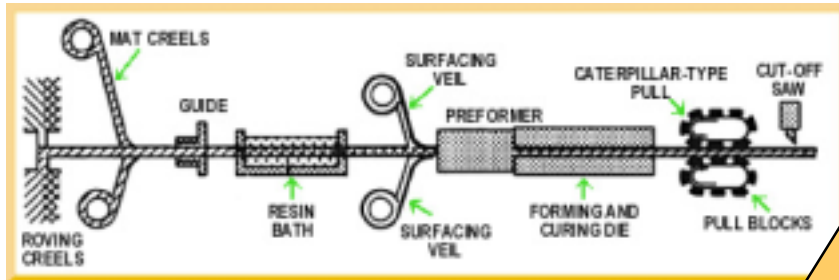
**Bergey
50 kW**



**Windlite
10 kW**



Example: Blades as High-Tech Spaghetti

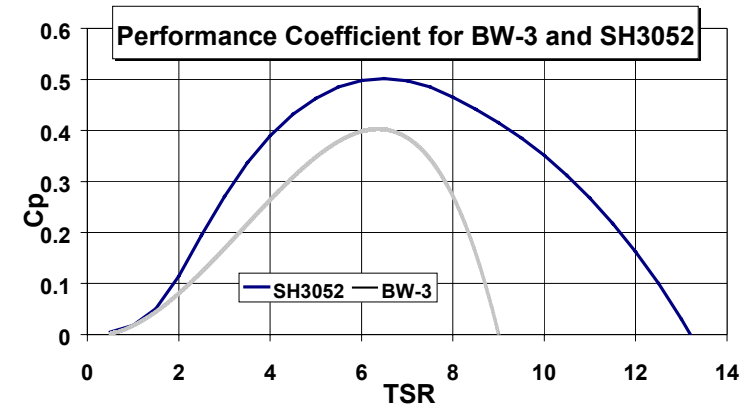


New Airfoil for BWC XL.50

Pultrusion Technology



BERGEY
WINDPOWER

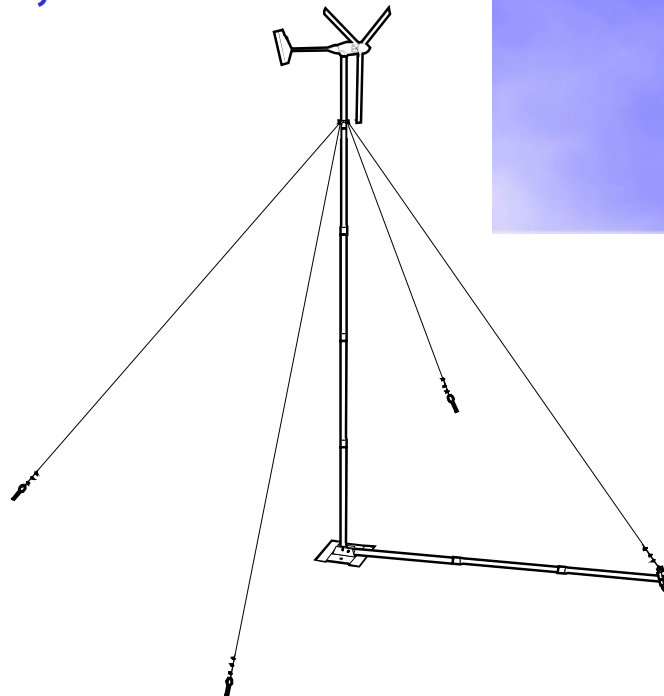
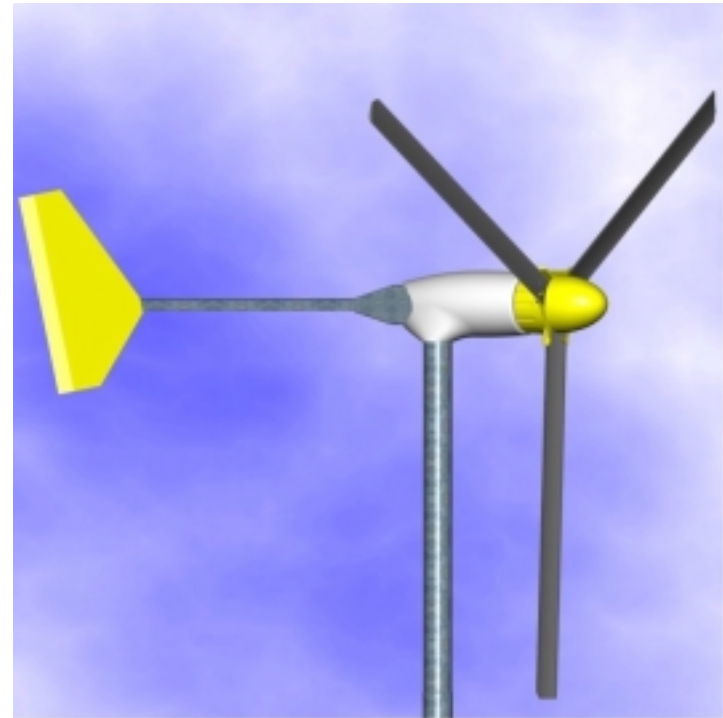


30% More Energy
25% Lower Costs
35% More Starting Torque

BWC XL.1

1 kW Wind Turbine

- ❖ 20-60% More Efficient
- ❖ Low Wind Boost Circuitry
- ❖ Typically Produces 3-10 kWh per Day
- ❖ Tilt-up Towers, 10-32m
- ❖ \$1,500 Retail

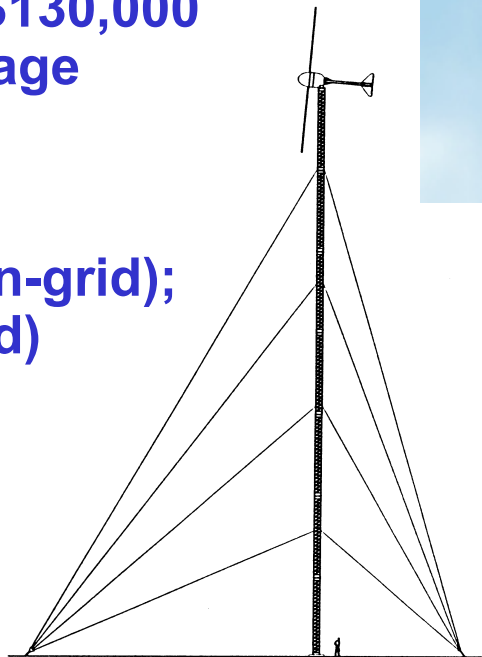


BWC XL.50

- ❖ Adapted ABB Variable Speed Drive for On-Grid & Off-Grid
- ❖ Designed to Work Well in Low Wind Areas (down to 3 m/s ave.)
- ❖ 150,000 kWh/Yr at 11.2 mph (170 ft Tower)
- ❖ Installed Cost: ~\$130,000 for Complete Village Power System
- ❖ First Deliveries: Summer, 2001 (on-grid); Fall, 2001 (off-grid)



50 kW



US-DOE has made **Small Wind** a Major Component of



Clean Energy for the 21st Century

14% of Native
American homes
have no electricity



Small Turbine Follow-up

- ◆ Numerous Manufacturers and Dealers around the world ... Find them on the Internet
- ◆ For listings of consultants, manufacturers, and project developers, use the Membership Directory of the American Wind Energy Association (www.awea.org)
- ◆ Design assistance available from small turbine manufacturers and DOE/NREL:

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